

Improving and Developing Predictive Backscatter Models of Fish

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LONG-TERM GOALS

The long-term goal of this program is to quantify, understand, and visualize acoustic backscatter from fish. Our strategy compares backscatter model predictions to laboratory and field measurements and integrates results in computer visualizations.

OBJECTIVES

Objectives of this research program include: incorporating transducer and fish directivity in predictive backscatter models, quantifying effects of ontogeny and pressure on swimbladder shape and resulting acoustical backscatter, and utilizing predictive backscatter models to develop target discrimination and classification algorithms.

APPROACH

The Kirchhoff-ray mode (KRM) backscatter model is used to predict acoustical backscatter as a function of acoustic wavelength, fish length, and fish orientation (i.e. aspect and roll). Backscatter predictions for individual or groups of fish are compared to *ex situ* and *in situ* field measurements, and then used in computer visualizations to integrate results. Rick Towler leads development of computer visualizations and revisions to backscatter modeling code. David Chevrier leads development of measurements and visualizations of computed tomography (i.e. CT) scans, and visualizations of multi-frequency data.

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WORK COMPLETED

Over the past several years, we have collected several hundred dorsal and lateral radiograph (i.e. x-ray) images of fish bodies and swimbladders. We are expanding swimbladder imaging techniques to include CT images. To continue collaboration within our research group and increase the potential for collaboration with other colleagues, we are revising our digital fish data file structure and format using Hierarchical Data Format (HDF). HDF is a platform-independent data structure developed at the National Super Computing Center.

Integrating backscatter model predictions with *in situ* backscatter measurements requires importing acoustic data collected by scientific echo sounders. We have developed computer algorithms to import acoustic data from Simrad EY500, EK500, and EK60 scientific echo sounders, and from SonarData's Echolog program.

Seven papers were published in the last year with an additional five papers accepted or in press, and three manuscripts submitted for review. A total of six presentations were made individually, jointly, or in collaboration with colleagues at regional, national, and international meetings.

East Coast

Computer algorithms have been developed to discriminate the fish body and swimbladder from extraneous 'noise' in CT scans of live and frozen fish specimens. We are developing swimbladder metrics (area, volume) and other quantitative metrics (e.g. thin-plate spline, conformal mapping) to quantify swimbladder shapes.

Multi-frequency echo sounder data collected during annual fisheries surveys in the Gulf of Maine and Georges Bank regions have been visualized in three-dimensions. These data are visualized jointly with geo-referenced bathymetric and water depth data obtained from the United States Geological Survey (i.e. USGS).

West Coast

Combinations of backscatter models and empirical measures have been used to complete numerous projects. The relative influence of physical and biological factors on backscatter intensity has been quantified using backscatter model predictions, dimensionless ratios, and target strength measurements of walleye Pollock (*Theragra chalcogramma*). Acoustic transmit and receive scattering models were combined to characterize the backscatter of paddlefish (*Polyodon spathula*), and the foraging of killer whales (*Orca orincus*) on chinook salmon (*Oncorhynchus tshawytscha*).

Incorporating scientific results in computer visualizations is an ongoing research effort. Enhancements to the backscattering ambit visualization have been added to exploit features in the development package. A camera object has been added to the collection of visualization tools that records a field of view using assigned location and aperture parameters, aligns the axis of the bounding box object, adds a flightpath along successive nodes, and a quaternion object to interpolate camera fields of view along the flightpath.

RESULTS

Our participation in the ICES Baltic Sea Herring Target Strength Study group resulted in backscatter predictions for 27 Baltic Sea herring and 25 European sprat. Comparisons of KRM predictions, *in situ* 38-kHz data, and experimental measurements suggest that fish target strengths are greater than those currently used by fisheries managers in the Baltic Sea.

East Coast

Computer algorithms were developed to separate the fish body and swimbladder from ‘noise’ in CT scans (Figure 1).

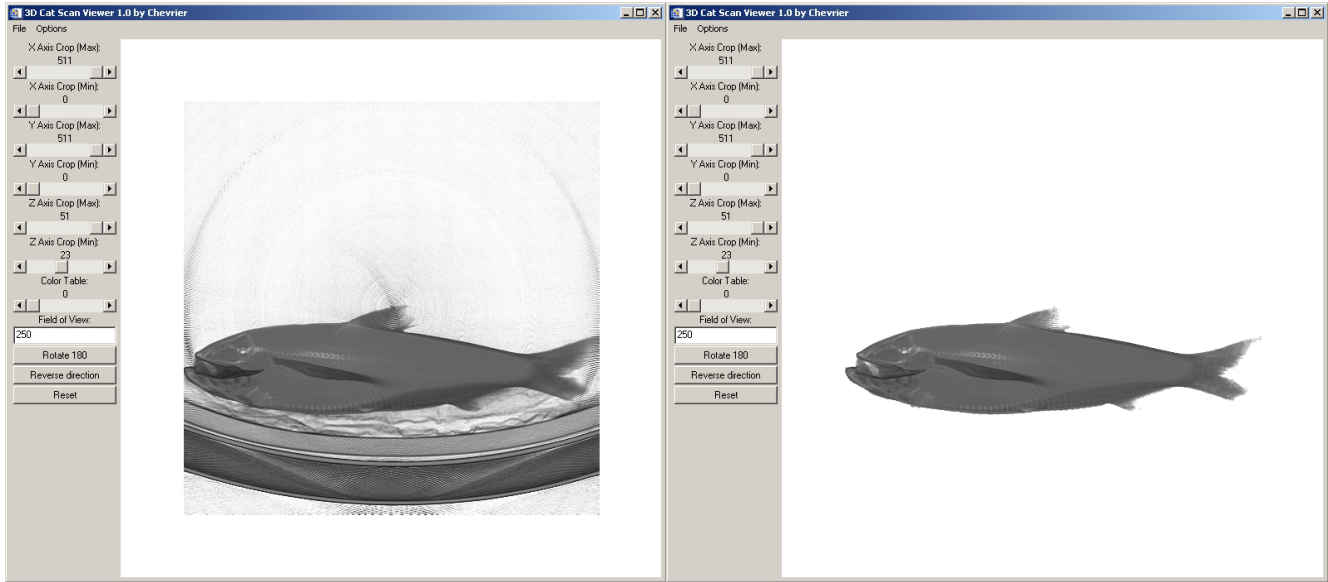


Figure 1. Single ‘slice’ from a CT scan of an alewife. The left panel displays the fish body and anatomical features such as the swimbladder and vertebral column with ‘noise’. The right panel displays the result of digitally removing extraneous x-ray scattering from the image.

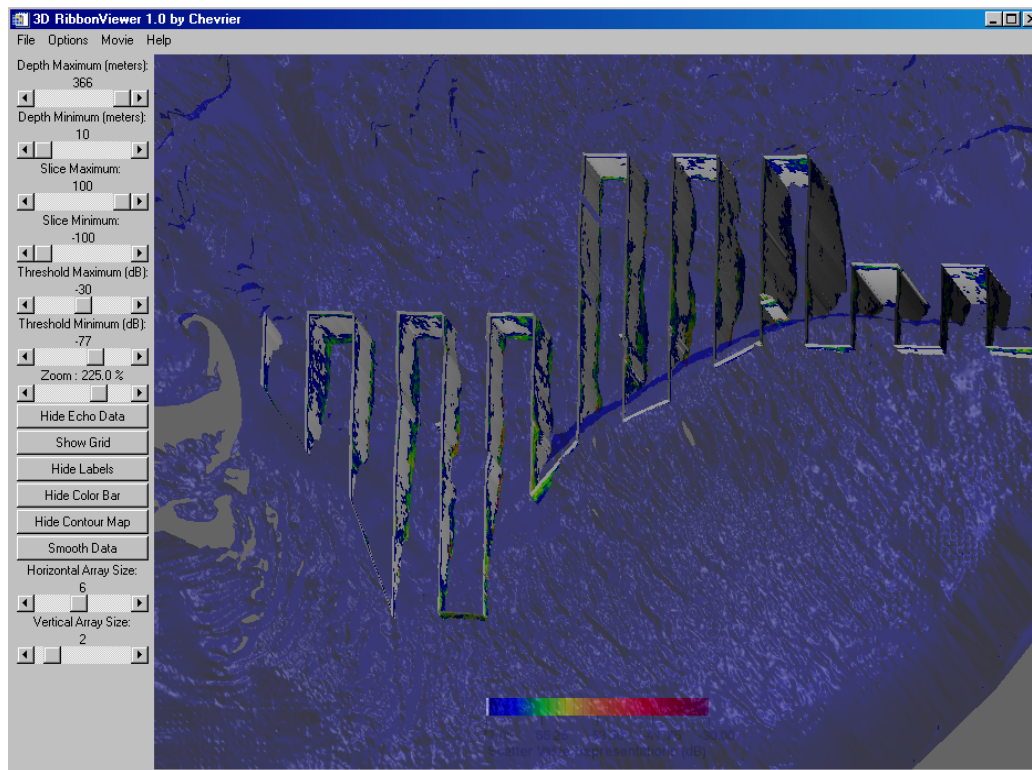


Figure 2. Three-dimensional visualization ('ribbon' plot) of 38 kHz echo sounder data collected during September 2002 on Georges Bank. Bathymetry is displayed as the blue surface, and the gray area on the left is Cape Cod, Massachusetts.

In situ echo sounder data are imported and visualized in three-dimensions (Figure 2). Bathymetric contours were obtained from the USGS. Echo sounder derived water column depths match the independently collected bathymetry. Acoustical data are horizontally scaled to geographic positions, and vertically exaggerated to highlight backscatter patterns.

West Coast

The relative importance of biological and physical factors influencing backscatter intensity differed depending on the data used to calculate and contour dimensionless ratio values. When factors were ranked using backscatter model predictions, fish tilt was the most important factor followed by acoustic insonifying frequency, fish length, and then depth. Using *ex situ* backscatter measurements, length was the most influential factor, followed by fish tilt, acoustic frequency, and then depth. The difference between the two rankings is attributed to differences in fish shape, which omitted in backscatter calculations when fish are scaled across a length range. This technique is now being used to compare factor rankings among different fish species.

The addition of a camera object to the visualization tool box eases the production of computer animations. Complex scenes can be recorded in single images or as visual 'fly-bys' to graphically illustrate an overall result and provide glimpses of visual detail. Figure three shows the interface used to define camera location and angle within an acoustic fish schooling simulation (Figure 3).

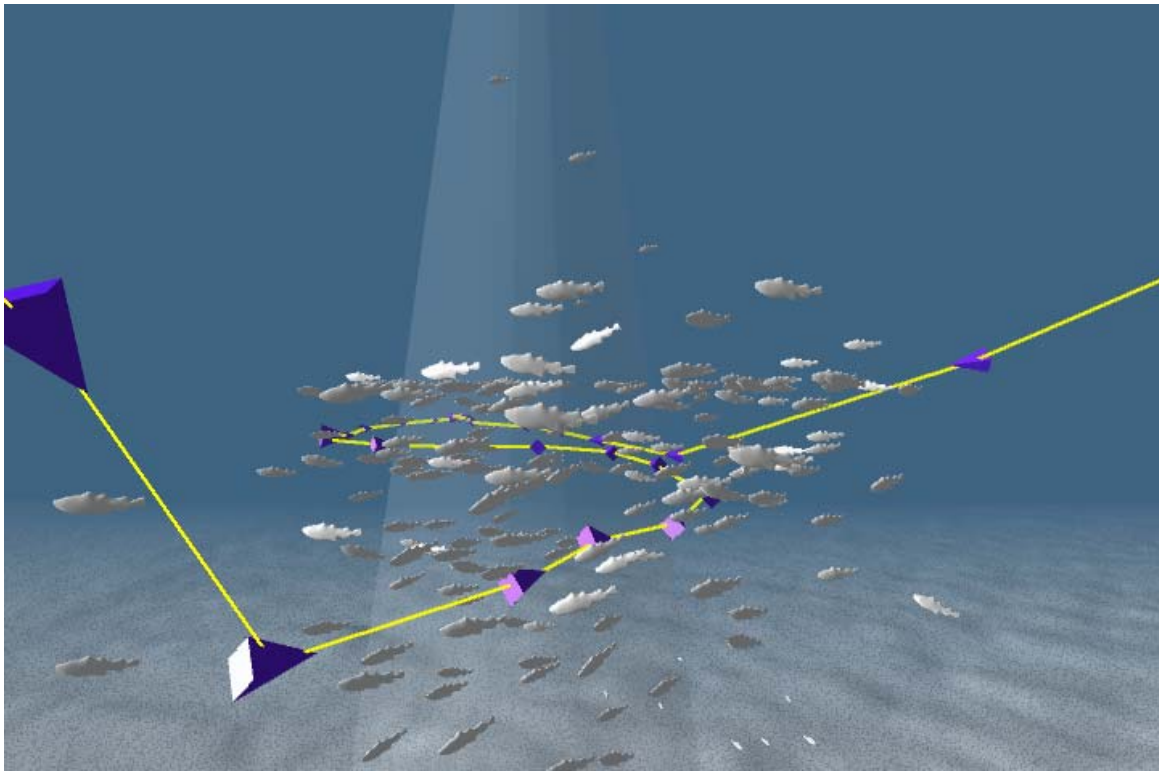


Figure 3. Screen capture of the camera nodes and flight path used in producing the fish schooling animation. The purple pyramids indicate the camera node position and orientation. The yellow line is the interpolated trajectory between successive nodes.

IMPACT/APPLICATIONS

A platform-independent, fish digital file format will improve collaboration among acousticians and fish biologists by providing a common, comprehensive database that can be used to test the influence of anatomy on acoustic scattering.

TRANSITIONS

Acoustic data collected in conjunction with underwater video images collected at the Northeast Fisheries Science Center are being used to incorporate fish behavior in conversions of acoustic data to fish length and abundance. KRM backscatter models and visualizations are being used in undergraduate and graduate courses at the University of Washington.

RELATED PROJECTS

Collaboration with scientists at the Woods Hole Oceanographic Institution to develop an acoustic calibration facility will improve our ability to incorporate KRM backscatter predictions in quantitative analyses of echosounder and multi-beam data. Collaboration with researchers using swimbladder resonance frequency acoustics will enhance our ability to classify and discriminate fish and invertebrate species.

KRM backscatter models are being used to characterize and examine the potential to acoustically discriminate fish species within the pelagic fish community of the Bering Sea and Gulf of Alaska. Results of these efforts are being used by researchers at the Alaska Fisheries Science Center to improve Pacific herring (*Clupea pallasii*) and walleye pollock abundance estimates, and to examine potential food resources for Steller sea lions (*Eumetopias jubatus*).

PUBLICATIONS

- Au, W.L., J.K.B. Ford, J.K. Horne, and K.A. Allman. Echolocation signals of free-ranging killer whales (*Orcinus orca*) and modeling of foraging for chinook salmon (*Oncorhynchus tshawytscha*). Journal of the Acoustical Society of America (in review).
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PRESENTATIONS

- Horne, J.K., N.J. Williamson, and J.C. Sweet. Bimodal target strength distributions: fact or fiction? ICES Fisheries Acoustics Science and Technology Working Group annual meeting. Bergen, Norway.
- Horne, J.K. 2003. Observing fish and mammals. Invited lecture. NEPTUNE Science Planning Workshop. Portland, Oregon.
- Horne, J.K. 2003. Bioacoustical ocean observatory thoughts. Invited lecture. Hawaiian Ocean Resources and Ecosystems Observatory Workshop. Keauhou, Hawaii.
- Jech, J.M., D. Chu, K.G. Foote, T.R. Hammar, and L. Hufnagle, Jr. 2003. Calibrating Two Scientific Echo Sounders. OCEANS 2003 MTS/IEEE Annual Meeting. San Diego, California.
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